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REPORT NO. T2/86

PHYSIOLOGICAL TESTING OF EXPERIMENTAL CHEMICAL WARFARE AGENT PROTECTIVE PATIENT WRAPS

US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE
Natick, Massachusetts

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UNITED STATES ARMY
MEDICAL RESEARCH & DEVELOPMENT COMMAND

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A physiological comparison of subject responses during 2 hours of encapsulation in the chemical warfare agent protective patient wrap currently being procured, six prototypes developed by the United States and a newly developed United Kingdom patient wrap was done in a warm environment (T_{db} = 29.90 (±0.46) °C, T_{dp} = 6.89 (±2.14) °C). Core temperature (rectal) and O_2 and CO_2 concentration within the wrap were measured every minute. Heart rate was measured every 5 minutes. Weight loss was measured before and after each experiment. The

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TECHNICAL REPORT
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PHYSIOLOGICAL TESTING OF EXPERIMENTAL CHEMICAL WARFARE AGENT PROTECTIVE PATIENT WRAPS.

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DISCLAIMER STATEMENT

The views, opinions and findings contained in this report are those of the authors and should not be construed as official Department of the Army position, policy, or decision, unless so designated by other official documentation. In conducting the research described in this report, the investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research. Human subjects participated in this study after giving their informed voluntary consent.

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Abstract

A physiological comparison of subject responses during 2 hours of encapsulation in the chemical warfare agent protective patient wrap currently being procured, six prototypes developed by the United States and a newly developed United Kingdom patient wrap was done in a warm environment (T_{db} = 29.90 ($\pm$0.46) ^{o}C, T_{dp} = 6.89 ($\pm$ 2.14) ^{o}C). Core temperature (rectal) and O_2 and CO_2 concentration within the wrap were measured every minute. Heart rate was measured every 5 minutes. Weight loss was measured before and after each experiment. The results showed that O_2 depletion and CO_2 accumulation after 2 h of encapsulation was less in the patient wrap made of a Nyco twill shell and 3M melt-blown polypropylene core and the patient wrap made of a Nyco Oxford shell and Lanton Mark IV core than the patient wrap made of a Nyco twill shell and a Von Blucker Saratoga shell. There were no significant differences in final core temperature or sweating rate during 2 h of encapsulation among the six prototypes. Further testing in a hot environment (T_{db} = 49.14 ($\pm$ 0.43), T_{dp} = 17.02 ($\pm$ 0.26) ^{o}C) revealed that there was less O_2 depletion in one patient wrap (Nyco twill/3M polypropylene) than in the wrap composed of a Nyco oxford shell and Bondina Mark IV core, although the two wraps were not different in a cold environment (T_{db} = -38.83 ($\pm$ 0.74)^{o}C).

INTRODUCTION

In the event of a military conflict in which chemical warfare agents are deployed, it would be necessary to protect casualties transported through such an area. To be prepared for such a situation, six chemical warfare agent protective patient wraps, each having the same general design, but composed of different materials have been developed. In order to evaluate which patient wrap causes the least physiological strain, human subjects were encapsulated in each of the six newly developed patient wraps. Oxygen (O_2) depletion and carbon dioxide (CO_2) accumulation in the patient wrap, and core temperature of the subject were measured. The six patient wraps were compared with each other, as well as to the old standard United Kingdom (U.K.) wrap and a new U.K. wrap.

After the initial experiments, two of the six experimental wraps were chosen for further evaluation in two extreme environments. The second series of experiments also provided preliminary data about safe exposure time during encapsulation in the two extreme environments.

MATERIALS AND METHODS

Eight chemical warfare agent protective patient wraps were tested: six experimental wraps, the standard U.K. wrap and a new U.K. wrap. The experimental wraps were composed of an impermeable ground sheet and an upper blanket of chemical protective, laminated cloth. There was a clear window in the upper blanket where the soldier's head was positioned. Each experimental prototype utilized the same materials for the window and ground sheet. The

window was a tri-laminated nylon/saran/polyethylene film. The ground sheet was Loretex and nylon. The shell and carbon based core materials of each experimental prototype varied (Table 1).

Table 1. Description of chemical warfare agent protective patient wraps.

	SHELL	CORE (CARBON BASED)
1.	NONE (Standard United Kingdom)	Bondina Mark IV
2.	Fire resistant cotton/Tyvek (New United Kingdom)	Modified Mark IV
3.	Nyco Twill	3M Melt Blown PP
4.	Von Blucher "Hylla"	Von Blucher Saratoga
5.	Nyco Oxford	Bondina Mark IV
6.	Nyco Twill	50 ml Polyurethane Foam
7.	Nyco Twill	Von Blucher Saratoga
8.	Nyco Oxford	Lantor Mark IV

Table 2. Individual characteristics of the subjects.

	Weight (kg)	Height (cm)	A_D (m^2)	Age	Resting Metabolic Rate (ml $O_2 \cdot kg^{-1} \cdot min^{-1}$)
1.	66.4	179.9	1.84	23	4.5
2.	75.5	175.4	1.91	21	4.0
3.	86.9	169.2	1.98	26	3.5
4.	67.3	171.8	1.79	22	4.5
5.	62.5	170.4	1.73	18	5.3
6.	79.0	179.7	1.98	19	4.7
7.	67.0	170.1	1.78	26	4.5
8.	92.3	177.6	2.10	27	4.1
$\bar{X}$	74.6	174.3	1.89	22.8	4.4
$\pm$ S.D.	(10.8)	(4.4)	(0.13)	(3.4)	(0.5)

Eight men (Table 2) volunteered to be tested. Resting metabolic rate was measured with an MMC Horizon System (Beckman) by standard procedures (1) while the supine subject was in a fasted state. Prior to the first experiment, each subject was familiarized with the patient wrap and the experimental protocol. The experimental design was a counterbalanced repeated measures design, so that familiarity to encapsulation would not affect data analysis. The counter balanced repeated measures design is the research design of choice any time there is reason to suspect systematic differences between successive measurements because experiments are planned so that each treatment is given first, second, ... to an equal number of subjects (2). With this extra control, any systematic effect of the order of treatment will not bias the comparison of

treatment means. The repeated measures design also decreases intra-treatment variablity (3), which will increase the power of the experimental design while minimizing subject number.

The experimental protocol for choosing the best patient wrap from a physiological basis was the same for each experiment. The experiments were conducted in an environmental chamber where T_{db} was 29.90 ($\pm$ 0.46) ^{o}C and T_{dp} was 6.89 ($\pm$ 2.14)^{o}C. The subject was dressed in battle dress uniform and boots. He inserted a YSI rectal temperature thermistor 10 cm past the anal sphincter for the measurement of core temperature (T_{re}). ECG electrodes and leads were attached for heart rate (HR) measurement. The subject was then weighed. A small diameter polyethylene tube, which was attached to a pump so that a continous air sample could be drawn from within the wrap, was then positioned at the bridge of the nose. The O_2 concentration of this sample of air was analyzed by an Applied Electrochemistry S-3A Analyzer. The CO_2 concentration was measured by a Beckman LB-2 CO_2 Analyzer. A dew point sensor (4) was attached within the patient wrap so that the dew point temperature (T_{dp}) within the wrap could be measured. He lay quietly for at least 30 min on the bottom layer of the patient wrap, ensuring that T_{re} was stable before the experiment began. The subject was then encapsulated in the wrap. O_2 concentration, CO_2 concentration, T_{re} and T_{dp} were measured every minute. Heart rate was measured every 5 minutes. Subjects were encapsulated in the wrap for two hours if O_2 concentration did not fall below 16%. In some cases, O_2 concentration fell below 16%, and the experiment was terminated. After the two hours of encapsulation, an impermeable film was fastened over the experimental patient wrap. O_2 and CO_2 concentration, T_{re} and T_{dp} were monitored every 30 sec and HR was measured every min after the film was

attached. The film was removed when the O_2 concentration fell to 16% (range = 1.5-21.1 minutes). The subject remained in the wrap for 20 min after the film was removed. Subjects were weighed after the experiment.

A one-way analysis of variance with repeated measures was used to determine differences between the wraps for change in T_{re}, sweating rate, and predicted T_{re} and weight loss after 6 h of encapsulation ($P < 0.05$). A two-way analysis of variance with repeated measures (wrap x time) was used to reject the null hypothesis for O_2 and CO_2 accumulation, T_{re}, T_{dp} and heart rate ($P < 0.05$). Tukey's test of critical differences was used where appropriate (5).

Two wraps were chosen for further testing in the two extreme environmental conditions. Six men were studied during two hours of encapsulation (no film attached) in hot (HOT/DRY, 49.1($\pm$ 0.43)°C, T_{db}; 17.0 ($\pm$ 0.26)°C, T_{dp}) and in cold (COLD/DRY, T_{db} = -38.83 ($\pm$ 0.74) °C) environments. The mean ($\pm$ S.D.) age, height, weight, DuBois body surface area (A_D) and resting metabolic rate of the subjects was 25.8 $\pm$ 5.7 years, 174.9 $\pm$ 4.8 cm, 74.9 $\pm$ 9.5 kg, 1.90 $\pm$ 0.11 m^2 and 0.27 $\pm$ 0.03 $l \cdot min^{-1}$ respectively.

In the hot experiments tropical uniforms were worn. A sample of air was drawn continously from within the wrap as explained for the initial experiments. CO_2 and O_2 concentration, T_{re}, HR and weight loss were measured as described above. The experiment was terminated if O_2 fell below 16%, T_{re} reached 39.2°C or if the subject felt incapable of remaining in the environment.

The subjects wore the full COLD/DRY ensemble (clo = 4.30 (6)) during the cold exposure. T_{re} and the index finger temperature (T_{finger}) were measured continuously. The experiment was terminated if T_{finger} fell below 10°C or if the subject felt too cold to remain encapsulated.

A one way analysis of variance with repeated measures was used to determine differences between the two wraps for the final T_{re} and O_2 and CO_2 concentration in the HOT/DRY environments, and for the final T_{re} and T_{finger} in the cold environment.

RESULTS AND DISCUSSION

Generally the subjects remained encapsulated for 2 hours, however, in a few cases the experiments were terminated before that time because O_2 concentration decreased below 16%. All subjects were encapsulated for 48 min at least, therefore time analyses of the data were done for that period of time.

Core temperature (T_{re}) increased as a function of time in all wraps. Wrap 1 (Table 1) was superior to all wraps in that it was most conducive to heat dissipation (Table 3 and Appendix 1). However, the increase in core temperature

Table 3. Mean (± S.D.) increase in core temperature (ΔT_{re}) during encapsulation, the ΔT_{re} predicted after 6 hours of encapsulation, and final heart rate (HR) during encapsulation.

	Wrap 1	Wrap 2	Wrap 3	Wrap 4	Wrap 5	Wrap 6	Wrap 7	Wrap 8
ΔT_{re}	0.07 (0.05)	0.21 (0.06)	0.21 (0.16)	0.30 (0.14)	0.21 (0.11)	0.25 (0.09)	0.22 (0.12)	0.25 (0.12)
Predicted ΔT_{re} after 6h	0.17 (0.10)	0.60 (0.31)	0.49 (0.34)	0.74 (0.29)	0.50 (0.23)	0.60 (0.20)	0.56 (0.29)	0.59 (0.27)
HR	71 (10.2)	81 (4.1)	79 (6.7)	82 (8.8)	84 (10.1)	80 (10.5)	78 (13.8)	73 (6.8)

during encapsulation was not significantly different among the prototypes (Table 3). The predicted increase in core temperature over a six- hour period in the

warm environment based on the measurements made in this study was also not significantly different. In this environmental condition (no solar load), subjects could be encapsulated in any of the wraps for up to six hours provided that the subjects were adequately hydrated (Table 4). It is critical to note that the subjects in these experiments were normally hydrated and were not sedated. Dehydration would result in decreased evaporation and elevated T_{re} (7) and would invalidate the 6-hr T_{re} prediction. Also, some types of analgesia could impair thermoregulation, so casualties to whom those types of analgesic agents have been administered would be less able to remain encapsulated in the wrap for long periods of time. Furthermore, any changes in the ambient conditions such as solar radiation, higher ambient temperature and higher relative humidity would invalidate the predicted change in T_{re} over a 6-h period of encapsulation. Any of these conditions would result in a higher T_{re} than predicted.

Table 4. Mean ($\pm$ S.D.) sweating rate during encapsulation and the predicted weight loss, based on this sweating rate, after 6 hours of encapsulation.

	Wrap 1	Wrap 2	Wrap 3	Wrap 4	Wrap 5	Wrap 6	Wrap 7	Wrap 8
Sweating Rate ($g \cdot min^{-1}$)	2.20 (1.37)	2.11 (0.86)	3.03 (1.20)	2.36 (1.57)	2.56 (1.33)	2.00 (1.06)	2.60 (1.31)	2.69 (1.24)
Predicted Weight loss after 6 h (kg)	0.79 (0.49)	0.77 (0.31)	1.09 (0.43)	0.85 (0.56)	0.92 (0.48)	0.72 (0.38)	0.94 (0.48)	0.97 (0.45)

The heart rate was not different among the experimental patient wraps, although the HR averaged 84 ($\pm$ 10) beats·min^{-1} in Wrap 5 which was statistically greater than Wrap 1 which averaged 71 ($\pm$ 10) b·min^{-1} (Table 3 and Appendix 1).

Sweating rate was not different among the patient wraps (Table 4 and Appendix 1). The predicted weight loss after six hours of encapsulation was not different among the various wraps (Table 4), although encapsulation for that length of time could result in moderate dehydration (in some cases up to 1.5% of body weight). Atropine results in approximately a 65% reduction in sweating rate in various environmental conditions (8). If casualties have been previously treated with atropine, T_{re} will rise much more rapidly than in untreated casualties, again invalidating the prediction of T_{re} after six hours of encapsulation.

Oxygen and carbon dioxide concentrations within the wrap were generally stabilized during the first twenty five minutes of encapsulation (Figs. 1 and 2). When the O_2 concentration was analyzed by a two-way analysis with repeated measures, including all subjects during the first 48 min of encapsulation (Subject 2 was removed from Wrap 5 at 48 min), Wrap 7 was less permeable to oxygen than Wraps 1,3 and 8. However, Tukey's test of critical differences revealed that oxygen concentration within Wrap 7 was not different from O_2 concentration in Wraps 2,4,5, and 6; and Wrap 5 was not different from Wraps 1,3 and 8 (Table 5). Therefore only Wrap 7 can be judged truly less permeable to O_2 as assessed by O_2 depletion encapsulation than the Wraps 1, 3 and 8. Even though the analyses show Wrap 7 to be less permeable to O_2 than wraps 1,3 and 8, the mean O_2 concentration was greater than 18% during the initial 48 min of encapsulation (Fig. 1). However, in three cases, the experiment had to be stopped due to O_2 concentrations less than 16% during encapsulation within Wrap 7.

Figure 1. The mean oxygen concentration during the first 48 min of encapsulation in Wrap 3 (▲) and Wrap 7 (■).

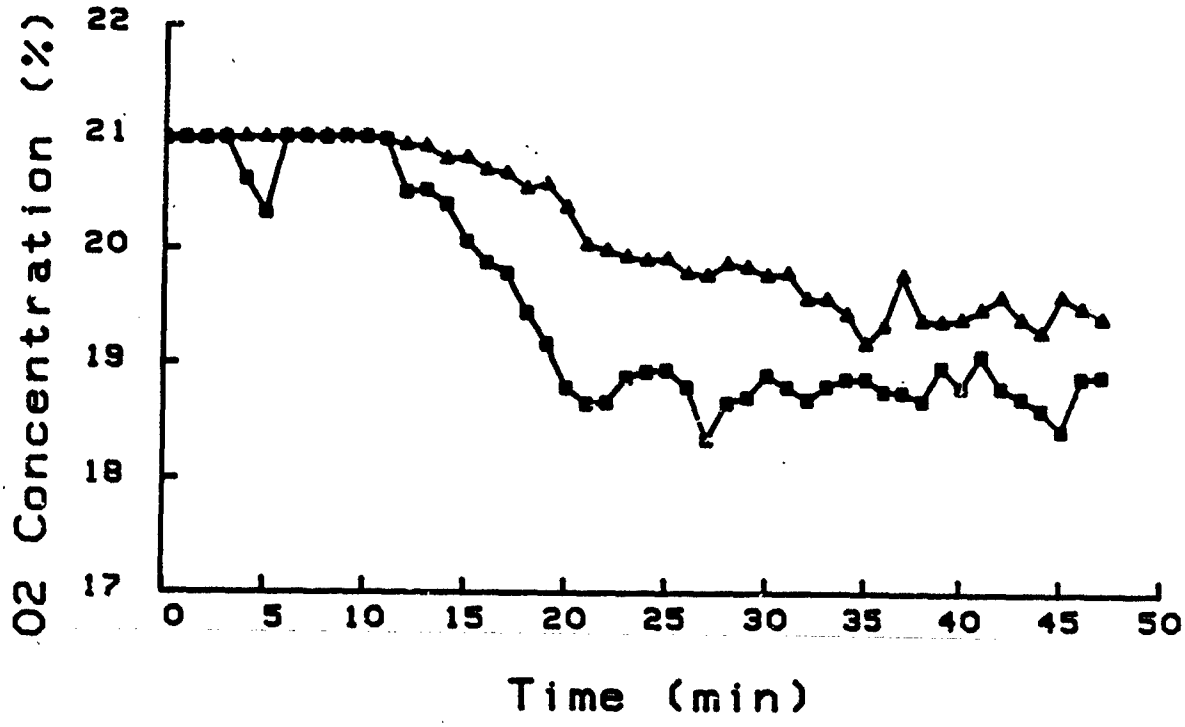

Figure 2. The mean carbon dioxide concentration during the first 48 min of encapsulation in Wrap 3 (▲) and Wrap 7 (■).

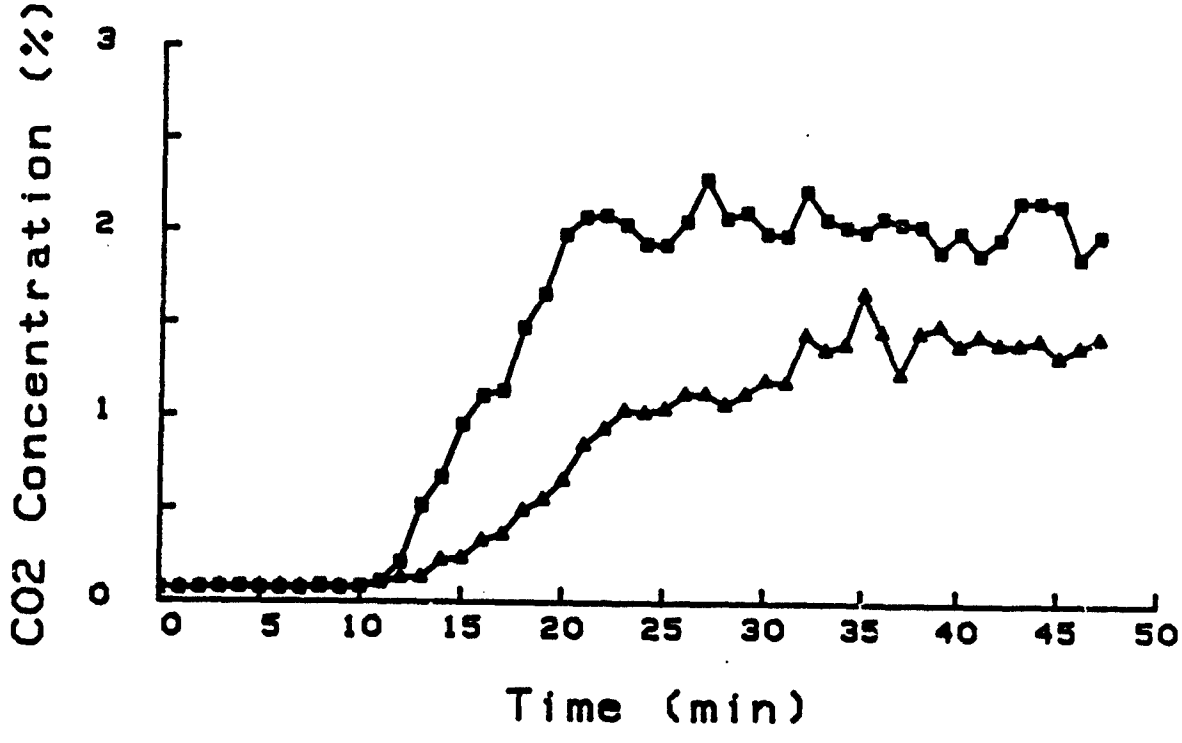

Table 5. Mean (± S.D.) oxygen (O_2) and carbon dioxide (CO_2) concentration within the patient wraps while subjects were encapsulated for the initial 48 min. The critial difference from Tukey's test (C.D.) is also presented.

	Wrap 1	Wrap 2	Wrap 3	Wrap 4	Wrap 5	Wrap 6	Wrap 7	Wrap 8
O_2 (%)	20.09 (0.8)	19.29 (0.9)	19.63 (0.9)	19.23 (1.0)	19.46 (1.0)	19.15 (0.9)	18.84 (1.2)	19.77 (0.7)
C.D. = 0.68								
CO_2 (%)	0.92 (0.6)	1.56 (0.8)	1.24 (0.8)	1.64 (0.8)	1.42 (0.8)	1.71 (0.7)	1.93 (0.9)	1.18 (0.6)
C.D. = 0.56								

CO_2 accumulation during the initial 48 min was less in Wraps 1,3, and 8 than Wrap 7 (Table 5). Wraps 2,4,5 and 6 were not statistically significantly different in CO_2 permeability from Wrap 7. However, the CO_2 concentration within Wrap 7 was considerably less than 3% during the initial 48 min of encapsulation (Figure 2 and Table 5). Based on the analyses of the initial 48 min of encapsulation, all the wraps would meet the letter requirement (O_2 concentation $\geq$ 18%, CO_2 concentration $\leq$ 3%) However, O_2 concentration decreased further over the entire two hours of encapsulation (prior to the placement of the impermeable film). Although in five cases, the experiment was terminated before two hours of encapsulation, a comparison of the O_2 and CO_2 concentrations within the wraps after two hours would be informative. Therefore in those cases in which the experiment was terminated, the last O_2 or CO_2 concentration measured was used as the 2 h value. The O_2 concentration was not different between Wraps 1,3,4,5,6 and 8 after 2 h of encapsulation, but O_2 concentration was clearly lower in Wrap 7 than in Wraps 1,3 and 8 (Table 6). Similar results were observed in CO_2 concentration after 2 h of encapsulation. Wraps 1,3,4,5,6 and 8 had a lower CO_2 concentration than Wraps 2 and 7 (Table 6); but Wraps 4,5 and 6 were not significantly different from Wrap 7. CO_2

accumulation was greater during encapsulation in Wraps 2 and 7 than Wraps 1 and 3. Also CO_2 accumulation was greater in Wrap 7 than Wrap 8. Thus, after 2 hours of encapsulation, Wrap 7 was less permeable to O_2 and CO_2 than Wraps 1,3 and 8.

Table 6. Mean (± S.D.) oxygen and carbon dioxide concentration within the patient wraps after 2 hours of encapsulation. The critical difference from Tukey's test (C.D.) is also presented.

	Wrap 1	Wrap 2	Wrap 3	Wrap 4	Wrap 5	Wrap 6	Wrap 7	Wrap 8
O_2 (%)	19.54	18.03	19.32	18.53	18.80	18.41	17.62	19.17
	(0.9)	(1.6)	(0.6)	(0.9)	(1.4)	(0.6)	(1.2)	(0.5)
C.D. = 1.27								
CO_2 (%)	0.98	2.31	1.18	1.90	1.62	1.95	2.61	1.43
	(0.6)	(1.2)	(0.5)	(0.8)	(1.2)	(0.7)	(1.1)	(0.5)
C.D. = 1.06								

During a 2 h encapsulation period in the environment in which the experiments were conducted, all of the experimental wraps were adequate according to the letter requirement except Wrap 7 (Table 6). Further testing was conducted on 2 prototype wraps in more extreme hot and cold environments. Wraps 3 and 5 were chosen because encapsulation in those wraps resulted in a lower T_{re} than the other prototypes (Table 3), although these differences were not statistically significant. Another consideration in choosing these two prototypes was that the production cost was estimated to be lower than some of the other prototypes.

Those experiments indicated that there were slight differences between Wraps 3 and 5. In the HOT/DRY environment, the majority of the subjects requested to be removed from both wraps before the end of the experiment. One subject's rectal temperature reached 39.2°C in both wraps and consequently was removed. The mean (± S.D.) time of encapsulation in Wrap 3 was 92.3 (±26.5) min and 94.6 (± 27.9) min in Wrap 5, which was not different between wraps

(Appendix 2). The final O_2 concentration during encapsulation was greater in Wrap 3 (Appendix 2). Although the final CO_2 concentration was not significantly different between wraps, there was a very strong trend toward significant differences ($p = 0.051$,, with Wrap 3 being less than 5. The concentration of O_2 in Wrap 5 did not fall below 18% and was only a 0.5% lower than in Wrap 3, although in higher altitudes this difference would become more important. Final T_{re} was not different between wraps. The predicted increase in T_{re} for 3 h of encapsulation in Wrap 3 was 2.2 ($\pm$ 0.6)°C and 2.1 ($\pm$0.6)°C for Wrap 5, and was also not different between wraps (Appendix 2). There was no difference in weight loss between the wraps. The average weight loss was 1.2 ($\pm$0.7) kg in Wrap 3 and 1.3 ($\pm$0.3) kg in Wrap 5. The predicted weight loss after 3 h was 2.2 ($\pm$ 0.9) kg in Wrap 3 and 2.5 ($\pm$0.6) kg in Wrap 5. There was no difference in heart rate between the wraps (Appendix 2).

The predicted T_{re} and weight loss during encapsulation in the HOT/DRY environment represent a substantial physiological strain (Appendix 2). An increase in core temperature which averages 2.2°C (3 h) could result in some heat injury casualties, even in men who were normally hydrated. In a field situation, the soldier would be further stressed by the combat situation and injury, as well as the environment. Proper hydration may be impossible in such a situation and would further increase the physiological strain. Encapsulation in the field for a longer time than the experimental subjects tolerated (~90 min) in these environmental conditions is contraindicated. If a technique for rehydrating the encapsulated patient is available, time of encapsulation without heat injury could be prolonged. Whenever sedatives, pain killers, atropine or other drugs used for protection against chemical warfare agents have been administered in the field, the time of encapsulation without heat injury would be reduced.

Furthermore, in these experiments it was observed that O_2 could be depleted to less than 16% in the area near the face during encapsulation when the subject lay with his face positioned upright such that the impermeable window of the wrap was pressed against the face. If the subject turned his head, the O_2 concentration would increase immediately. An unconcious or sedated patient would be more likely to suffocate, while a conscious patient who was able to turn his head would have little possibility of suffocation.

In the -40°C environment there were no differences between wraps (Appendix 2). The time of encapsulation averaged 76.5 (± 10.6) min in Wrap 3 and 68.6 (± 10.3) min in Wrap 5. T_{re} decreased 0.65 (± 0.4)°C in Wrap 3 and 0.46 (± 0.2)°C in Wrap 5. T_{finger} decreased 16.4 (± 5.2) °C to 14.45 (± 5.0)°C in Wrap 3 and 14.2 (± 4.2) °C to 14.8 (± 5.2)°C in Wrap 5. Weight loss was neglible in both wraps, and heart rate was not different between wraps. Predicted T_{re} at 3 h, where differences between the two wraps would be maximized, were not significantly different. T_{re} was predicted to decrease 1.49 (+ 0.7)°C in Wrap 3 and 1.27 (+ 0.6)°C in Wrap 5 (Appendix 2). Predicted finger temperatures after 3 h were not different between wraps. In both, the fingers would suffer cold injury. Table 7 shows the mean predicted core and finger temperatures for 90, 120 and 180 min during encapsulation. It must be kept in mind that these predictions are for nonstressed subjects dressed in the full Arctic ensemble, which included 3 layers of insulation (clo = 2.18 (6)) for the hands. After 90 min of encapsulation in a -40°C environment, a small portion of the population could suffer cold injury to the phalanges. The instances of cold injury would increase with 2 h of encapsulation.

Table 7. Mean (+ S.D.) predicted rectal temperature (T_{re}) and finger temperature (T_{finger}) during encapsulation in -40°C (n = 5).

	90 min		120 min		180 min	
	Wrap 3	Wrap 5	Wrap 3	Wrap 5	Wrap 3	Wrap 5
T_{re}	-0.75	-0.64	-0.99	-0.85	-1.49	-1.27
(S.D.)	(0.4)	(0.3)	(0.5)	(0.4)	(0.7)	(0.6)
T_{finger}	-19.38	-20.13	-25.84	-26.84	-38.76	-40.26
(S.D.)	(7.6)	(7.2)	(10.1)	(9.6)	(15.1)	(14.5)

CONCLUSIONS

All the prototype patient wraps exceeded the letter requirement for O_2 depletion, CO_2 accumulation and core temperature during a 2 h encapsulation period in a warm environment except for the wrap made of Nyco twill shell and a Von Blucher Saratoga core (Wrap 7). By 2 h of encapsulation mean O_2 concentration within this wrap had decreased to less than 18%. Both O_2 depletion and CO_2 accumulation was statistically different in Wrap 7 than Wraps 1,3 and 8. In the HOT/DRY environment, O_2 depletion was significantly less in the patient wrap composed of a Nyco twill shell and 3M melt blown polypropylene core than a wrap made of a Nyco oxford shell and Bondina Mark IV core. There were no significant differences in core temperature and finger temperature between the two patient wraps when tested in the -40°C environment.

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Appendix 1

The statistical table for one-way analysis of variance with repeated measures. The F-value (F), the F probability (F-prob) and critical differences (C.D.) are listed for sweating rate, predicted 6h weight loss (6h ΔWt) final changes in T_{re} (ΔT_{re}), predicted 6h T_{re} (6h T_{re}), final O_2 concentration (O_2) and the final carbon dioxide concentration (CO_2).

	SR	6hΔWT	ΔT_{re}	6h T_{re}	O_2	CO_2	HR
F	0.740	0.729	3.452	3.484	5.524	5.601	2.463
F-prob	0.640	0.648	0.0044	0.0042	0.0001	0.0001	0.0301
C.D.	-	-	0.162	0.396	1.269	1.059	13.0

Appendix 2

The statistical table for one-way analysis of variance with repeated measures for both the HOT/DRY and COLD environments. The mean data for Wrap 3 (W3) and Wrap 5 (W5), the F-values (F), the F probability (F-prob) and critical difference (C.D.) are listed for weight change (Δ wt), final change in T_{re} (ΔT_{re}), predicted 3 h T_{re} (3 h T_{re}), final O_2 concentration (O_2), final CO_2 concentration (CO_2) and time of encapsulation (time) in the HOT/DRY environment, and weight change (Δ wt), final change in T_{re} (ΔT_{re}), predicted 3 h T_{re} (3 h T_{re}), final change in finger temperature (ΔT_{finger}), predicted 3 h T_{finger} (3 h T_{finger}) and time of encapsulation (time) in the COLD environment.

HOT/DRY

	ΔWT	ΔT_{re}	3 h T_{re}	O_2	CO_2	Time
W3	-1.20	1.17	2.19	19.07	0.95	92.25
W5	-1.27	1.14	2.09	18.57	1.44	94.58
F	0.20	0.05	0.26	13.98	6.53	0.20
F-prob	0.67	0.82	0.63	0.01	0.051	0.68
C.D.	-	-	-	0.34	-	-

Cold

	ΔWT	ΔT_{re}	3 h T_{re}	ΔT_{finger}	3 h T_{finger}	time
W3	-0.23	-0.66	-1.49	-16.36	-38.76	76.50
W5	-0.13	-0.46	-1.27	-14.23	-40.26	68.58
F	1.67	4.39	4.77	1.41	0.07	1.43
F-prob	0.25	0.10	0.09	0.30	0.80	0.29
C.D.	-	-	-	-	-	-

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